research review

OAR The Research Agency of The United States Air Force

VOLUME III NUMBER 9 NOVEMBER 1964

A New World Record ....

Quarter-Million Gauss Sustained at the National Magnet Laboratory

MAX SWERDLOW, Directorate of Physical Sciences, AFOSR

The most intense continuous magnetic field yet generated by man has been produced by scientists at the AFOSR-sponsored National Magnet Laboratory at MIT. Two hundred and fifty-five kilogauss* have been sustained in a water-cooled modified Bitter magnet by D. Bruce Montgomery and his associates. The highest d.c. magnetic field previously recorded was 152 kilogauss achieved about two years ago at the Naval Research Laboratory, Washington, D.C.

The NML magnet was first brought up to a peak 255,000-gauss field on 30 October 1964. The experiment was repeated several times that day. The magnetic field was measured to 205 kilogauss with a coil and an electronic integrator based on a nuclear magnetic resonance calibration. The field to 255 $\pm$ 2.5 kilogauss was measured with a bismuth magnetoresistance probe. At peak field, the high-performance magnet drew 10.5 megawatts of electrical power from the laboratory's four d.c. giant motor-generator units. The magnet was cooled by 1800 gallons of purified water per minute.

One kilogauss equals 1000 gauss. A gauss is a unit of measurement of magnetic field intensity. The natural magnetic field of the earth, which aligns the compass needle, is about one half gauss.

The design principle employed in the NML 250-kg magnet is that of three concentric coils, each contributing to the field strength at the core of the inner coil. The principle is a major advance in magnet design. The three coils together make up a cylindrical nest about three feet in diameter and two feet high. (See Figure 1.)

The 2-1/8-inch-bore magnet is comprised of three concentrically nested coils having internal diameters of 2.5 inches, 6.5 inches and 14 inches, respectively. These generate 73, 82 and 50 kilogauss, respectively. The final 50 kilogauss to reach the world's highest d.c. field yet generated is obtained by inserting two iron-pole tips in the central air core. Three tons of copper have been used in the 250-kg magnet. Only a half ton is normally used in a 125-kg magnet of the

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same internal diameter. Cooling the magnet and withstanding the enormous stresses of magnetic forces on the copper plates constitute the principal design problems. Montgomery's successful solutions result from the use of copper Bitter disks[1] with radial cooling passages for high-heat transfer. Support of the copper plates, which are subjected to stresses of 60,000 psi, is obtained by the use of thin insulated stainless-steel strips placed between each copper plate in helical arrays. (See Figures 2 and 3.)

Experiments with the high-performance NML magnet will continue. Montgomery and his colleagues expect to be able to push the peak continuous field to 300 kilogauss and to produce 2-second pulsed fields approaching 500 kilogauss. This is the newest development in a large complement of magnets at the National Magnet Laboratory.[2]

The facility includes a 10-MW dc supply capable of 1-minute overloads to 16 MW and 2-second overloads to 32 MW, 10 experimental stations, and a number of high-field magnets of various configurations. The 10 experimental stations are designed to accommodate interchangeable magnets and rotating experiments so that a large number of experiments can be run in a relatively short-time period. The power supply consists of 4 independent generators, each with its own regulating system so that up to 4 magnets can be operated simultaneously. The generators are operated in parallel when magnets require larger input power. The magnets are cooled by a closed-loop system of pure water circulating at several thousand gallons/minute. The basic regulation system provides stabilities of 1 part in 10^4; and a separate flux feedback system bypassing the main power supply can give short-term stabilities and ripple cancellation of 1 part in 10^6 to 1-kc frequencies.

The present complement of standard magnets includes four 2-1/8" 110-kilogauss solenoids, three 2-1/8" by 1-1/8" transverse access solenoids, with fields up to 100 kilogauss, and two 4" 80-kilogauss magnets, one with 1-1/8" transverse access.

The complement of experimental magnets

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Fig. 1. D. Bruce Montgomery, staff member at the National Magnet Laboratory, makes adjustments in experimental apparatus mounted atop the laboratory's giant new water-cooled magnet. The magnet is capable of generating the strongest magnetic field yet made by man--255,000 gauss. The magnet, a solenoid which utilizes three concentric copper coils, was designed by Mr. Montgomery and his associates and is just being brought into use for experiments aimed at probing the fundamental magnetic properties of matter.

includes a 2-1/8" 200-kilogauss solenoid, two 1-1/4" 160-kilogauss magnets, one 2-1/8" 120-kilogauss variable transverse access magnet, one 14" 50-kilogauss coil, and one 4" 65-kilogauss high-homogeneity high-stability magnet for nuclear-magnetic-resonance work. During the coming year, two 2-1/8" 150-kilogauss solenoids, one 1-1/4" 200-kilogauss solenoid, and one 4" 150-kilogauss solenoid will be built in addition to the continuing developmental programs on the present experimental magnets at the NML.

Magnetic fields have long had an important role in the study of the physical world. Their importance for industry, technology, and applied science, of course, is well known. In recent years, however, the use of magnetic fields in basic research has accelerated rapidly, extending into such widely separated domains as high-energy physics, geophysics and biophysics, and covering the study of diverse forms of matter: elementary particles, gases, liquids, plasmas, and solids. The great potential and versatility of this major scientific tool has only just begun to be realized. The coming years may prove to be even more exciting, in the variety and depth of discoveries anticipated on a wide range of unexplored physical phenomena.

A magnetic field exerts a force on a moving charged particle, and a torque on a magnetic dipole. Through these basic microscopic interactions on the components of the atom, the field produces macroscopic effects in solids, liquids, gases and plasmas. These

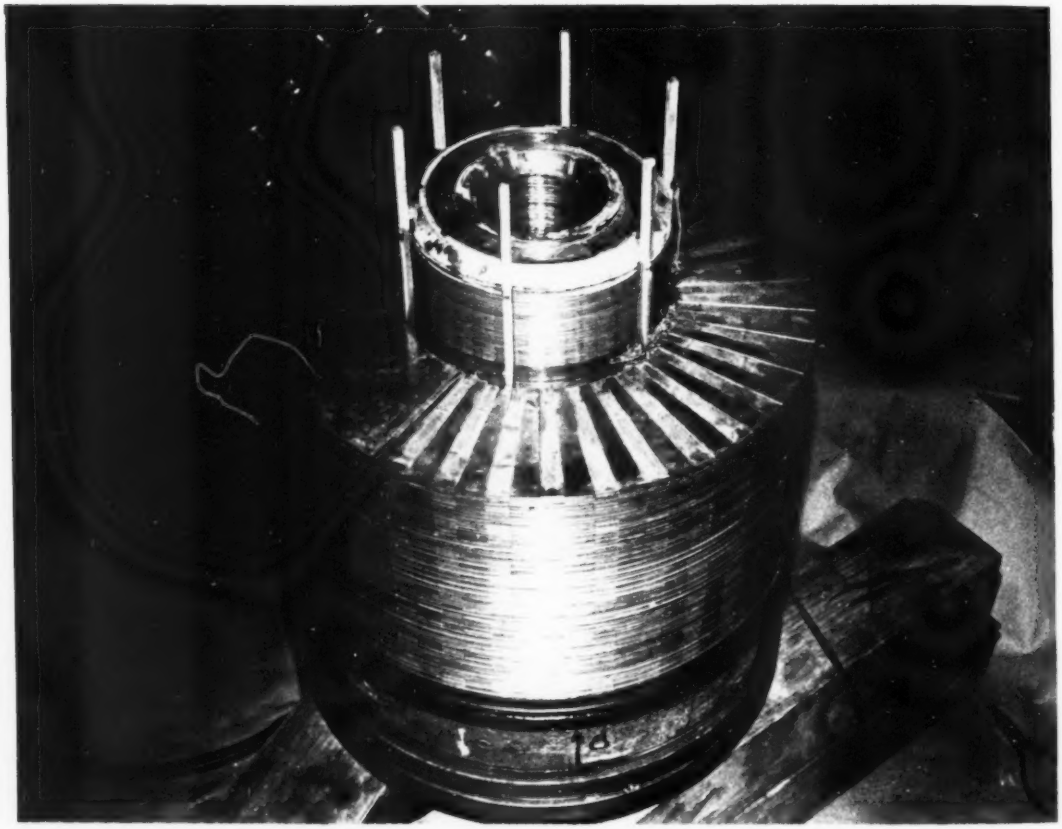

Fig. 2. Inner sections of 250-kG water-cooled magnet during assembly. Each section is a helix made of stacked copper plates with radial cooling channels. (See schematic view of plates in Figure 3. Copper plates are supported by insulated steel strips.)

forces can be observed directly as, for example, in the deflecting system of the television picture tube, or in the attraction of iron objects by magnets. The indirect effects of magnetic forces on the properties of matter are strongly dependent on the types and arrangement of atoms, and the forces between them. Thus, through careful study of the indirect effects of a magnetic field on matter, much can be learned about the structure of specific materials and about the general physical laws governing the behavior of all matter.

In this respect, magnetic fields are analogous to other environmental factors which can be used for the study of matter, such as pressure, temperature and electric field. Over the last 50 years, magnetic fields have been employed in a wide variety of important scientific experiments. Several examples from atomic physics were: the measurement of the charge-to-mass ratio of the electron (which constituted its discovery); the identification of the various particles emitted in the radioactive decay of nuclei; and the study of Zeeman effect in atomic spectroscopy (which provided important data for the development of quantum mechanics). In more recent times, in solid-state physics, magnetic fields have been widely used in such experiments as cyclotron resonance, nuclear magnetic resonance, electron paramagnetic resonance, the Hall effect, Mossbauer effect and the Faraday effect.

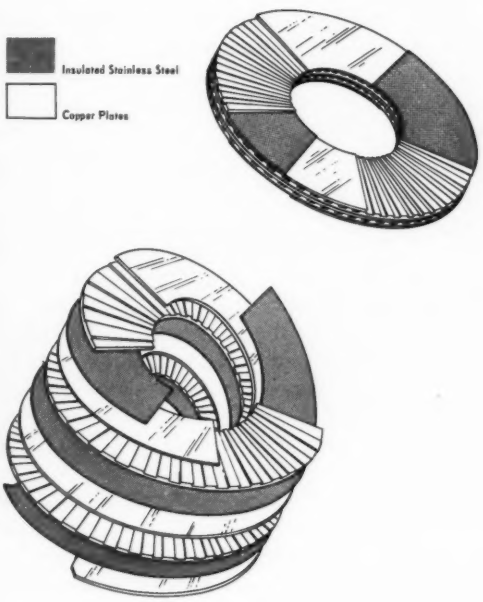

Fig. 3

With the great activity in solid-state physics after World War II, the need for even higher fields became apparent. A principal objective in solid-state physics has been the elucidation of the band structure or allowed energy-level structure of electrons in solids. Many of the experiments used for determining band structure, such as magnetoresistance, Hall effect, cyclotron resonance and magnetic susceptibility, become more effective as the magnetic field is increased. In many materials, useful data can be obtained only when the fields used are above 30-50,000 gauss.

With intense magnetic fields, cyclotron resonance phenomena may be examined over the spectral range extending from millimeter to near-infrared wave lengths. Thus, cyclotron resonance techniques may now be extended to new materials which heretofore could not be investigated because imperfections in the crystal increased the natural line width at the lower frequencies and lower magnetic fields. Among these classes of materials are semiconductors, semimetals, metals, and optically excited insulators.

With the use of fields in excess of 100,000 gauss, antiferromagnetic, ferromagnetic, ferrimagnetic and electron-spin resonance phenomena can also be observed in the millimeter to infrared wave-length interval. In many cases this represents an extension, with greater precision and resolution, of existing experiments into a new regime. In other situations, operation at high frequencies is essential in order for the experiment to be feasible at all. For the first time, nuclear magnetic resonance can be extended into the UHF domain, (centered around 1500 megacycles), making possible investigations with greater sensitivity and precision in a host of materials.

Optical techniques have provided valuable basic knowledge about atoms, molecules and,

to a lesser extent, solids. Today, however, with the availability of high-quality single crystals of many materials, low-temperature techniques, and the high-magnetic fields, magneto-optical phenomena[3] have become a basic tool for solid-state investigation in a manner analogous to atomic spectroscopy. Many experiments on free holes and electrons in metals, semimetals, and semiconductors can be performed, and interband phenomena involving complex energy bands can be investigated.

Experiments concerned with the physics of solids will be centered around high-field superconductors, magnetoacoustical effects, magneto-optical phenomena involving lasers, galvanomagnetic properties, and De Haas-van Alphen effects, to give some examples. Other experiments in plasma physics, magnetochemistry and biomagnetics will also be possible.

All of these experiments using intense magnetic fields should, in the next several years, yield a high rate of quantitative data on materials whose electronic structure has been unknown or poorly understood until now. This information will be the basis for future developments by applied physicists and engineers who are concerned with the electrical, optical, and thermal properties of materials.

The potential consequences of such investigations can be most significant. From them may emerge new and more efficient means of generating and transmitting electric power.....magnetohydrodynamic generators.....magnetic fields to confine plasmas in thermonuclear reactors...inductive storage of vast amounts of electrical energy...refrigeration by direct energy conversion...high-resolution electron microscopes and spectroscopes...outer-space applications ranging from magnetic-field shields against charged radiation to superconducting gyroscopes for inertial-guidance systems of improved accuracy... millimeter- and submillimeter-wave generation and ultrasonic devices for new frequencies for communication. But of principal importance will be the basic data and the properties of atoms and aggregations of atoms in solids, liquids and gases. Fundamental understanding about the behavior of matter under extreme conditions of environment is the ultimate goal of the National Magnet Laboratory. Such knowledge is not only tomorrow's most important tool, but is also the key to aerospace superiority. ★

[1] *Bitter, F., "The National Magnet Laboratory at the Massachusetts Institute of Technology," Brit. J. Appl. Phys., Vol. 14, Nov. 1963, pp. 759-765.*

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Montgomery, D. B., "The Generation of High Magnetic Fields," Decennial Conference on Magnetism and Magnetic Materials, Nov. 16, 1964.

[3] *Swerdlow, Max, "Magneto-optical Laser," OAR Research Review, Vol. III, No. 1, Mar. 64, pp. 1, 6-8.*

ION-BEAM SYNTHESIS

MAJ CORNELIUS J. DONOVAN
Directorate of Engineering Sciences, AFOSR

A new technique for the synthesis of chemical compounds has been developed through an AFOSR contract with the Rocketpower Research and Development Laboratories of the Maremont Corporation, Pasadena, California. Pure nitrobenzene was synthesized in high yield by bombarding the benzene molecule with a beam of NO_2^+ ions under carefully controlled conditions. The apparatus used consists of (1) an ion source capable of providing a low-energy (1 electron volt) high-current (1 milliampere) beam of selected ionic species; (2) an electrostatic potential control or accelerator for extracting the current from the source and giving accurate ion energies on the order of one electron volt; (3) a reaction vessel in which the ions interact with the target molecules to produce a chemical reaction; and (4) a cold trap to collect the products of reaction.

Reactions involving ionic intermediates which are ordinarily run in the liquid phase can now be investigated in the gas phase. The ion reactions are carried out by the interaction of a beam of ionic reagent with a

neutral target gas.

The success of the ion-beam synthesis was realized by the development of a modified magnetron to provide the accurately controlled current and exact voltage. If the kinetic energy of ions in the beam exceeds one electron volt, fragmentation of the polyatomic ions or neutral target molecules will occur.

In carrying out the synthesis of nitrobenzene, liquid dinitrogen tetroxide (N_2O_4) was admitted to the ion source and a beam of 99+% of pure NO_2^+ ions was formed which had no detectable quantity of any other ion. Reaction of the beam with gaseous benzene was followed by collection of the condensable gases flowing from the reaction chamber. Analysis of the product by gas chromatography indicated that the NO_2^+ beam reacted entirely to form nitrobenzene and no other compound could be detected even in trace quantities. The infrared absorption spectrum of the products was the same as that of pure nitrobenzene. Experimental investigations were made to determine if the reaction would take place between neutral (un-ionized) nitrogen dioxide and benzene. Also, the gaseous reagents were irradiated with an intense light to attempt photolysis. The results were negative and showed therefore that the gaseous reaction could take place only in an ionic reaction.

Several other gases have been studied in the ion source, and polyatomic beams of NF_2^+, OF^+, H^+ and CN^+ have been produced. In extending the reaction mechanism to additional synthesis, NF_2^+ ions were directed at benzene targets. A substance with the chromatographic properties appropriate to $C_2H_5NF_2$ was obtained. Further confirmation of the identity of this compound is being obtained. This compound was previously unknown, and the reaction by which it was made represents the first ionic reaction in which NF_2 species have taken part.

This new synthesis technique may lend itself in the future to the formulation of new high-energy propellants by combining atoms in ionic synthesis into compounds which cannot be formed by other means. ★

COMMUNICATION by BRAIN WAVES

MICROWAVE PHYSICS LABORATORY
AFCRL

With a little practice, some people can alter the pattern of their brain's alpha rhythm. When this is done, it is possible to communicate, purely by thought control, with the outside world.

This doesn't mean that such people will be able to read each other's minds, but simply turn their alpha rhythms on and off in a manner that will allow them to use binary digits (or Morse code) for communication. By using binary digits, a person can communicate very efficiently.

Dr. Edmond M. Dewan of AFCRL originated the concept of using the brain's alpha rhythm for communication. He designed the instrumentation for detecting voluntary changes in brain-wave patterns, and has successfully--and rather dramatically--demonstrated the feasibility of the technique.

Dewan has designed a device to detect alpha-rhythm patterns--low-frequency brain waves (about 10 cps) related to visual perception. The alpha rhythm is usually found in the normal human adult when he is relaxed and has his eyes closed. It is "blocked" or turned off by opening the eyes. Many people can even block their alpha rhythms with their eyes closed, simply by imagining some scene or object.

Dewan's device picks up the brain's electrical signals through leads attached to the scalp, and amplifies them in much the same way as an electroencephalograph does. It then selects the alpha rhythm by means of a 9-14-cps band pass filter. A special switch is activated when the alpha rhythm is on for more than a very short time. Thus, by blocking his alpha rhythm in the appropriate manner, the user can send coded signals without moving a muscle.

Dewan has successfully demonstrated his device to several doctors by operating it with his own alpha rhythm. He has sent Morse code, but it is a slow process--about 15 seconds per letter. ★

Droplet Size Measurement by Light Scattering

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The convenient measurement of the size distribution or mean droplet size sprays encountered in various propulsion devices has been a problem that has plagued the field for many years. Difficulties are encountered because of the wide range of particles in the spray, the evaporative property of most sprays, and the fact that the sprays contain particles which are moving. Because of pressure and temperature conditions, collection of particles has not been generally feasible. Photographic measurements have been applied with some success, but require numerous pictures because of depth of field limitations and the tedious job of counting and sizing of the numerous particles.

Under Air Force Office of Scientific Research sponsorship, Dr. I. Glassman and his colleagues at Princeton's Guggenheim Laboratories for the Aerospace Propulsion Sciences have developed a very convenient and readily applied method for measuring the mean droplet size of evaporating sprays. The technique is based upon the small-angle diffractive scattering of light. This interesting method already has been applied and found useful for evaluating rocket injectors, spray nozzles, etc. (see e.g. Ref. 1). This article describes the Princeton method.

We start by considering what happens when light falls upon a spherical body. Now the direction of propagation of light incident to a transparent spherical body is known to be altered by several effects. Light directly impinging upon the particle is refracted and reflected, or simply reflected. Successive internal reflections weaken the intensity of a ray within the sphere due to refractive escape of a fraction of the energy. In addition, there may be internal absorption of luminous energy and conversion to thermal or chemical energy. Rays which are not incident directly upon the sphere but which pass in close proximity also are diverted from rectilinear propagation, in this case by diffraction. The totality of the above effects is referred to as the scattering of the light by the particle. Rays which are affected by the proximity of the drop are diffractively scattered while those incident upon the drop are referred to as non-diffractively scattered.

The above description applies when the diameter of the sphere (D) is large compared to the wave length of light (λ). If this condition is not fulfilled, then it is necessary to apply electromagnetic theory in order to determine the effect of the sphere on the incident electromagnetic radiation (light). The more general electromagnetic theory reduces to the special optical case when $D >> \lambda$. By an appropriate choice of λ (usually in the visible range), the above requirement for practically all cases of interest in propulsion devices is met and the method developed is based upon this simpler formulation.

Further, consider an experiment in which a beam of parallel monochromatic light of circular cross section is incident upon a sphere. A device to measure luminous flux is then placed in a plane normal to optic axis (see Figure 1). Since the sphere is considered to be on the optic axis as well, a conical half angle (θ) is subtended by the receiver's position, the particle, and the optic axis at the receiver plane. If this conical half angle is small, the luminous flux nondiffractively scattered within the angle is small and can be ignored. Thus, in the method to be discussed, θ is kept small and only the intensity of small-angle diffractively scattered light is measured.

Diffraction theory which gives the intensity of small-angle scattered light is found in many books (see e.g. Ref. 2). The following expression is found for the intensity (I) of light diffracted by a single spherical particle when exposed to illumination (E_O) of collimated

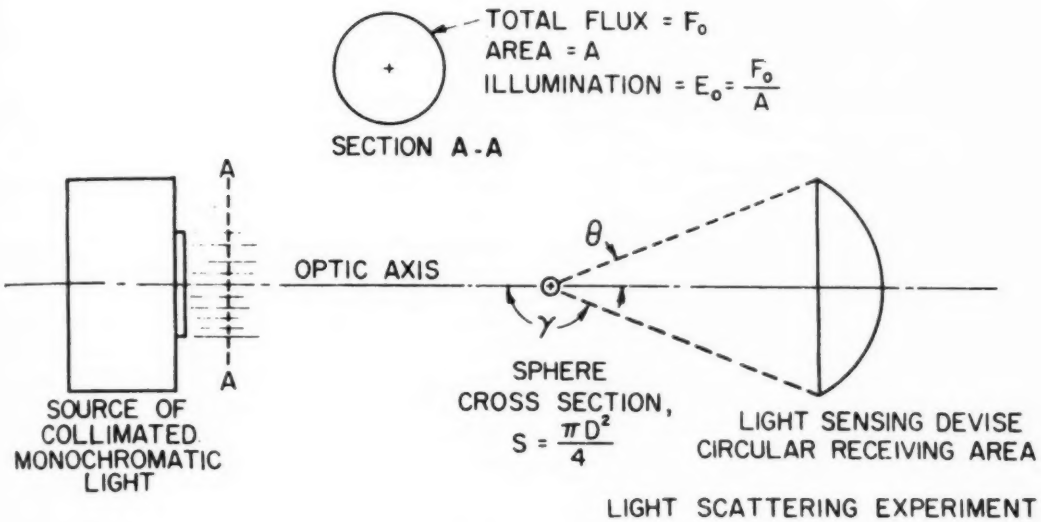


Fig. 1

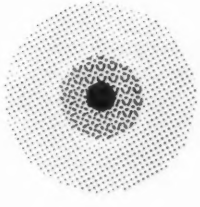
monochromatic light.

$$I = E_o \left(\frac{\pi D^2}{4\lambda}\right)^2 \left[\frac{2J_1 (\alpha \sin\theta)}{\alpha \sin\theta}\right]^2$$

α is the droplet size number, $\pi D/\lambda$. J_1 is the Bessel function of the first kind of order unity. Such functions are representations of series, in this case, of the variable ($\alpha \sin\theta$). In essence, the expression gives the variation of intensity with the angle θ . Since such Bessel functions can oscillate and go to zero for particular values of ($\alpha \sin\theta$), the above expression predicts the existence of light and dark rings ("diffraction rings"). In essence, these diffraction rings can be looked upon as interference fringes. In fact, the droplet can be considered to act exactly as the two slits in Young's classic experiment to show interference fringes (see Ref. 3). The edges of the droplet diametrically opposite from each other act like the slits. Instead of obtaining longitudinal interference fringes as one obtains with the slits, one finds rings with the droplet.

If one could superimpose the diffraction rings of various-diameter particles using the same monochromatic light, the actual ring pattern would be obscured and a gradual variation of intensity from the center outwards would be found (see Figure 2). Since we are interested in a spray which is made up of large numbers of droplets of all different sizes, the problem arises as to how one can superimpose the patterns of the individual particles which make up the spray.

Representation of a diffraction pattern of a single particle or many particles of the same size.



Representation of diffraction patterns of many particles of different sizes superimposed.

Fig. 2

Reference 4 shows that the simple optical arrangement sketched in Figure 3 does this in essence and in fact much more. The scattered light in the reception plane is shown to be the same as though each particle were located at the principal point of the receiving lens regardless of the actual position of the particle in the incident beam. This result has all these important consequences:

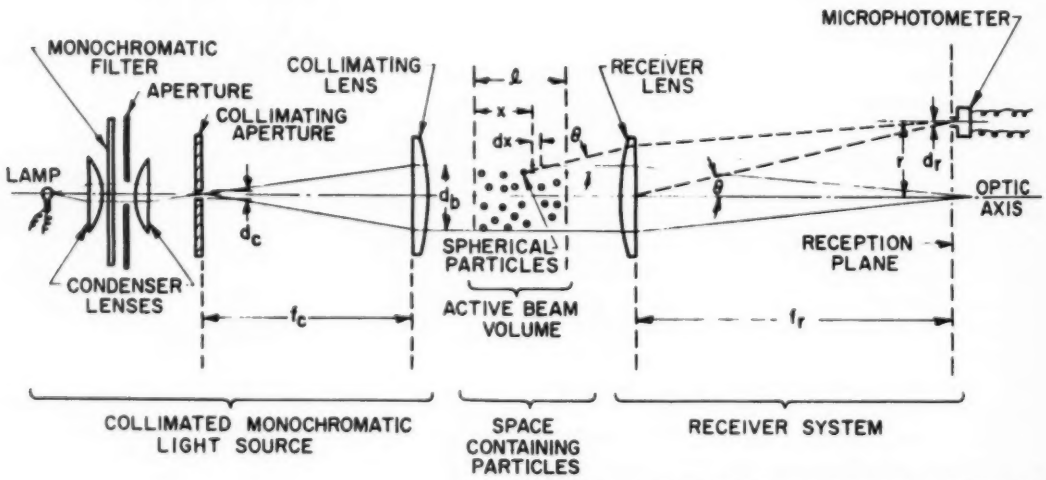
1. A particle moving within a beam of light produces a diffraction pattern in the reception plane identical to the pattern produced by the particle fixed in space within the beam. The optical system therefore displays an apparent motion-stopping capability.

2. A group of particles present within the beam will produce a scattered light pattern that is the same as though each particle were located independently at the principal point of the receiving lens, provided that multiple scattering is absent or negligible. Thus, the optical system has the property of superimposing or integrating the diffraction patterns produced by a large number of particles.

3. The integrated diffraction pattern created by a group of particles in continuous motion through the collimated beam will remain steady in time provided the concentration and size-distribution of those particles contained within the beam are independent of time.

Thus, using the optical arrangement shown in Figure 3, one can obtain instantaneously the intensity of variation of the small-angle diffractively scattered light by placing a piece of photographic film at the reception plane. The equation previously given for the variation of intensity is then modified to include all sizes of particles in the spray. This modification is carried out mathematically most conveniently by assuming that the particle distribution can be represented by some distribution law. The so-called Upper-Limit Law is the most suitable (Ref. 5). It is then possible, from measurement of the intensity variation with θ and measurement of the attenuation of the beam's light intensity, to calculate the particle size variation. However, the accuracy of measurement demanded is such that different size distributions cannot always be distinguished. Nevertheless, the mean particle size based on the volume-to-surface-area ratio, $\overline{D}_{32}$, is sensitive to the measurements. The $\overline{D}_{32}$ is the significant mean diameter for combustion experiments. The detailed mathematics is given in Dobbins' thesis (Ref. 4).

In order to measure the intensity variation on film with sufficient accuracy, the Prince-



SCHEMATIC DRAWING OF OPTICAL APPARATUS

Fig. 3

ton group had to extend the ability to use photographic photometry over ranges of intensity not previously thought possible. This feat was accomplished by perfecting photographic-development techniques, accurate film calibrations, and extending the range of available microdensitometers. This photometry work is reported in Ref. 6. ★

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6. *Dobbins, R. A., L. Crocco and I. Glassman, "Wide Range Photographic Photometry," Rev. Sci. Inst., 34, 1963, p. 162.*

SCIENTIFIC NOTES

AFCRL Analytical Technique Adopted as Standard: Providing the essential reference points of research are mutually agreed-upon standards for measurement, calibration and analysis. Where national or international bodies have not or cannot establish official standards, quasi-official standards emerge and gain wide recognition as a kind of common language. In the field of chemical analysis, Scotts Standard Methods of Analysis has become such a standard. The revised edition of Scotts Standard Methods of Analysis will include in one of its chapters the neutron activation method for the analysis of silicon. This method was developed by J. Paul Cali and others of the Air Force Cambridge Research Laboratories. The methods described in Scotts are considered to be standards where precise and accurate analytical methods are required in quality control and other applications.

(Solid State Sciences Laboratory, AFCRL)

Investigations In Non-Causal Field Theory

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General Physics Research Laboratory, ARL

The most fruitful formalism which is used today in many areas of physics is the approach known as quantum field theory (QFT). Observable quantities such as the strain in a solid, the pressure in a liquid, the electromagnetic field, and even the metric tensor of space and the wave function of a particle have been treated as fields to be quantized, and their properties then calculated by this method. However, there are some severe, even insuperable difficulties with QFT as presently formulated. In an attempt to provide explanations or even solutions to some of these difficulties, an alternate formalism, here called non-causal field theory (NCFT), has been developed. The attempt does indeed remove some difficulties; as usual, however, new ones, perhaps more serious, have arisen in their place. But the exercise is not yet complete, and the full meaning and scope of the new method is yet unknown.

To explain the new approach, let us review some of the postulates of QFT. One assumes that, at a certain time, he can specify the values of a certain set of observables at every point in space. This is the initial field distribution. One then wishes to discover, through the dynamics of the system, the values of all these observables at every point in space, at any later (or even earlier!) time. He accomplishes this through two devices: (a) the canonical equations of motion, and (b) the Hamiltonian. The Hamiltonian is a function of the coordinates and momenta of the system. The canonical equations say that the time derivative of any observable of the system is equal to (a constant times) the commutator of that observable with the Hamiltonian. Different Hamiltonians then will describe different systems: electrons, mesons, gravity, etc. The problems are to choose a Hamiltonian which yields equations of motion actually satisfied by the physical quantities

as determined by experiment, and then to find solutions of the canonical equations.

The new approach is an outgrowth of the ideas of the special theory of relativity, specifically, that time is a coordinate of any system on equal footing with the usual spatial coordinates x, y, z. The question is posed: what happens if one assumes, then, that one is free to specify as initial conditions the values of his observables, not just at all points of space, but at all points of space and all times? The question would be empty unless one had a dynamic principle which would allow one to calculate the behavior of such a system. This dynamic principle is the chief result of the present work.

The crux of the NCFT is the assumption that the values of these observables would change, but change in a manner which minimizes a certain "action" integral while keeping another function Ω (essentially, the total mass of the system) constant. From this, one obtains a set of equations of motion which give the development of all the observables of space-time as a function of a parameter, τ . If one chooses the function Ω properly, one finds that, among the solutions to the canonical equations of motion are a set of field operators which, in addition, obey the ordinary equations of motion of, say, a meson field, and which do not depend on the parameter τ at all.

What are these fields? They are of two types: those which depend on τ and those which do not. The ones which do depend on τ are surely not physical fields, for if one specifies the value of the field quantity at a certain point and at a certain time, it will change at the whim of a parameter τ which is neither space nor time. So these are called noncausal. The special set of fields which do <u>not</u> depend on τ are stationary in the sense that if one specifies these field values for all space-time properly, one has such a special field and there will be no change in these values, regardless of the parameter τ . But then one finds that an arbitrary specification is not allowed; the values of the field variables at different points of space-time must be related in order to have one of this special set. Most importantly, one finds that the relation which must exist is just that these field variables must obey the ordinary space-time equations of motion; the Klein-Gordon, Dirac, Proca, or similar equations. Where this relationship exists, however, we know that our only real freedom is to pick the values of the variables on a space-like surface; all others are determined by the particular equation of the system. Accordingly, these special fields are called the causal or physical fields, and are a subset of the general solution to the problem.

What, then, does this approach give us? First, it gives us a completely symmetric way of treating fields as functions of space and time. This is a powerful guide to investigating any problem. Second, it gives us an over-all picture of a problem. One might liken the old QFT approach, developing the solution in time, to driving down a highway*; and the new approach to viewing the landscape from a balloon. If we are looking at a physical system, the landscape is quiet, stationary. However, if we are looking at a nonphysical system, the landscape heaves and tosses. But third, the mathematics of computing the results for a particular problem is somewhat different, and different in ways which remove some of the divergences of QFT in an intuitively satisfactory way.

As stated earlier, other problems have accompanied these results. These problems are chiefly ones of interpretation. Whether they will be satisfactorily resolved, and whether the application of the resulting formalism to the old problems will yield useful results must await further investigation. The formalism is essentially complete. It has been applied to the free scalar meson, vector meson, and Dirac fields. The results of these applications have been strikingly similar, for the physical fields, to those of the QFT. However, even for these simple examples, some new results have been obtained. Some new fields are predicted; some integrals which diverge in QFT do not diverge in NCFT. The present work is directed toward computing perturbation results, chiefly scattering cross sections. ★

*apologies to R. P. Feynman, Phys. Rev., 76:749, 1949

Universal Launcher Thermal-Control System

CHURCHILL RESEARCH RANGE, OAR

Introduction:

The Churchill Research Range is located at Fort Churchill, Manitoba, Canada, on the shores of Hudson Bay. This geographical location is reputed to be the coldest spot in North America. The mission of the Range is the launch of upper-atmospheric and near-space probes in support of the scientific research of both the United States and Canada.

Function:

Beginning in early September of each year and continuing through April of the following year, a major percentage of the rockets launched by the range are in support of scientific investigations into the phenomenon of Aurora Borealis. This phenomenon occurs almost nightly and in varying degrees of intensity. The Universal Launcher facility of the Range is so designated because of its multiple capability as a launch facility. The range can launch five different Black Brant rockets, the Nike-Cajun, the Nike-Apache, the Astrobee-200, and the Javelin (ARGO D-4) rockets from this one launch facility. This multiple capability resulted in the designation of Universal Launcher.

Problem:

In the scientific investigations relating to the phenomenon of Aurora Borealis, the primary objective is usually the placing of a sounding rocket with its instrumented pay load into the center of an active element of the phenomenon at its greatest intensity. The major problem in accomplishing this task is the fact that these auroral events are usually from 6 to 10 minutes in duration and of varying depth and intensity. During the period when a launch is scheduled to fire a probe into an event of this type, it is necessary to have a reaction time of 3.5 minutes or less in order to insure that the scientific pay load can be launched into the auroral event.

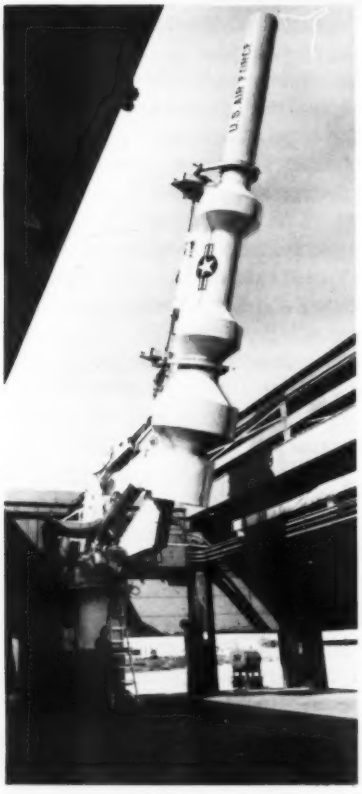
Experience has dictated that the only satisfactory method for accomplishing this task is to count the rocket down to within 3.5 minutes or less of firing time and "hold" until the phenomenon occurs in the desired intensity and on the desired trajectory as specified by the project scientist directing the investigation. Within this framework, a problem has been created that has required some original design and development to provide a satisfactory solution.

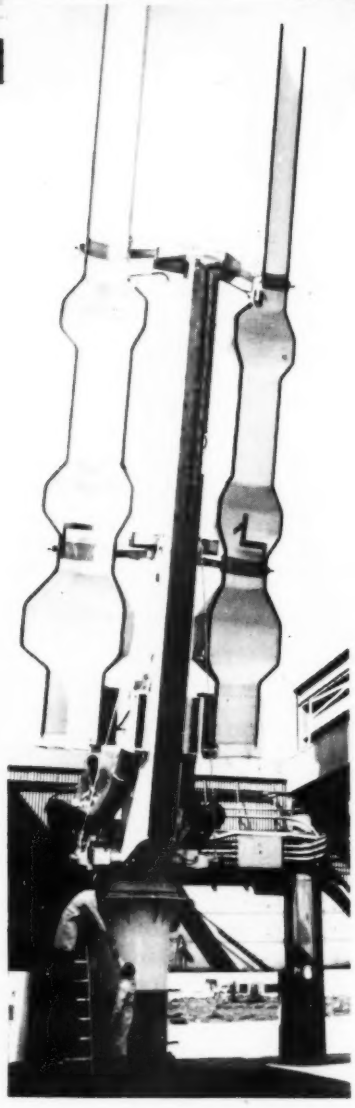
The rockets which can be launched from the Universal Launcher, listed above, are all solid-propellant-type rocket vehicles. These particular propellants are temperature-sensitive and, consequently, must be provided with some type of thermal protection during the prelaunch periods in the winter months. The temperature range of the rockets launched from the CRR Universal Launcher facility is from 0^{o} F to $+60^{o}$F. Clearly, in the Churchill location where temperatures range from $+85^{o}$F to -50^{o}F, further complicated by high-velocity winds, the propellant temperature limits could only be met through an artificial thermal-control system.

In the effort to launch into auroral events from the Universal Launcher, the rocket was subject to exposure to the ambient temperature for periods of as long as four hours. Due to the propellant temperature limits, this was prohibitive. This limitation reduced the range capability to support auroral investigations to an extremely low level, and dictated a requirement for the design of a satisfactory thermal-control system for the positive control of rocket-motor temperatures when a launch countdown was in progress.

Solution:

The solution to the problem has been the design of a unique thermal-control system which has, in effect, provided the Churchill Re-





Three views of the boom-mounted, fiberglass, clam-shell-type shroud, one of the three basic elements of the unique Universal Launcher Thermal-Control System at the Churchill Research Range, Fort Churchill, Manitoba, Canada. The three sections of the clam-shell-type shroud can readily be seen in the photo showing the shroud in the open position.

search Range with a firm 3.5-minute reflex capability. In many instances, this can be reduced to 90 seconds, further enhancing the range capability to support auroral investigations.

The thermal-control system which was designed and installed on the Universal Launcher has proved to be a most efficient and necessary element of the diversified range-support system. The system as accepted and installed consists of 3 basic elements: (1) a boom-mounted, fiberglass, clam-shell-type shroud that separates at the center and opens and closes around the rocket vehicle when it is attached to the launcher rail; (2) a heating system, external to the launch bay, composed of two remotely controlled portable air units. These units are kerosene-operated and can concentrate high levels of heating power in a small package. They are rated at approximately 400,000 BTU/hr; (3) two remote-control units for control of the thermal system during the launch countdown period and during those periods when maintenance is being performed on the system. One control unit is located in the blockhouse for use by the test conductor, and the other is located adjacent to the launch bay for use by maintenance personnel.

Noting in more detail the three systems listed above, the fiberglass shroud is designed to provide thermal protection for all rockets launched from the Universal Launcher. The clam-shell-type shroud is configured to accommodate these various rocket vehicles without alteration or adjustment. Each shell half was fabricated in three sections (top, middle, bottom) which butt each other at the holding hinge-arm locations. The top section of the closed shell is a straight cylinder which cantilevers beyond the upper hinge arm. The fin enclosures are approximately cylindrical in section and incorporate conical transition sections to increase rigidity.

The drive mechanism for the clam shells is mounted on two gear reduction boxes. The geared system was chosen over the hydraulic system because of its compactness, simplicity and efficiency, and because synchronized hinged motion as well as positive locking capability at any stop position are obtained. The clam-shell shroud can either be opened or closed in 32 seconds.

The heating system consists of the two previously listed portable-type heating units. These are de luxe Herman-Nelson heaters which are remotely controlled from the blockhouse and from the maintenance console. Sensing units located inside the fiberglass shroud provide a constant-temperature monitor when the system is in use. The controls available on the console permit the starting, stopping, speeding up, and slowing down of either or both of the heating units. Additionally, the hot air can be "dumped" from the shroud if necessary. The heating units are located in a building external to, and separate from, the launch bay. The heat is piped into the shroud through large flexible pipes commonly referred to as "elephant trunks."

The control system consists of the two consoles located as indicated previously. These consoles provide the test conductor and the launch supervisor with 100 per cent remote control of the thermal-control system. The clam-shell shroud can be opened and closed, the temperature can be monitored, and all functions of the heating system can be remotely controlled from these consoles.

Conclusion:

Undoubtedly, the thermal-control system described above is unique throughout the world. Its design and development was dictated by the geographical location of the Churchill Research Range and by the Auroral Borealis phenomenon that occurs in abundance at this remote arctic location.

This thermal-control system has provided the Churchill Research Range with a capability and flexibility that permit the needs of the scientific community to be satisfied in all instances where investigation of the Aurora Borealis is the primary objective. The required 3.5-minute reaction time of the scientist who endeavors to investigate this strange phenomenon is now truly a reality. ★

OAR Profiles

Dr. Donn G. Shankland of the General Physics Research Laboratory, ARL, writes in this issue of the Review on "Investigations in Non-Causal Field Theory." Dr. Shankland has a B.S. in Physics from the University of Washington, Seattle, Washington (1950), and an M.Sc. in Physics (1955) and PhD. in Physics (1961), both from Ohio State University, Columbus, Ohio. From June 1950 to December 1958, he served with the U.S. Air Force, reaching the grade of captain. He received the Air Medal (3o1c), the Korean Service Medal, the U.N. Medal and the National Defense Ribbon.

Mahlon Hunt of AFCRL compares a photograph of the lunar crater, Guericke, taken by the Ranger-7 satellite with a lunar chart of the same area. These items are contained in a special "Moon Room" established at AFCRL. In this room, lunar maps, mosaics, atlases, lunar photographs from astronomical observatories, and Ranger-7 lunar photographs have been brought together in a permanent, open display. These items will serve as important source materials in AFCRL's study of selenodesy, which deals with determining the precise size, shape and gravity of the moon.

Strengthening MgO Crystals by Alloying

LT COL RALPH W. CONNERS
Directorate of Physical Sciences, AFOSR

The possibility of strengthening a ceramic crystal by alloying has been demonstrated in the system Mg-Fe-O by G. W. Groves and M. E. Fine of Northwestern University, working with AFOSR support. By quenching and aging an MgO crystal containing a per cent of two of the cation Fe^{3+}, a finely dispersed precipitate of magnesioferrite can be developed. This will, for example, triple the flow stress of an already slightly impure MgO crystal when iron has been added to a concentration Fe/Mg + Fe = 1.35%.

Alloy crystals were prepared from relatively pure MgO crystals by diffusing in coatings of iron which had been vacuum-deposited on the surface. The crystals were held at 1400° C. in air for long enough to obtain a sensibly uniform concentration of iron in a 0.1-mm.-thick crystal. Since the crystals initially contained ~ 50 parts per million (ppm.) of Fe, as well as ~ 300 ppm. of Al and Ca, the effect of very small additions of Fe was not studied. Figure 1 shows the strengthening effect of iron in crystals quenched from a solution heat treatment in air at 1400° C. No precipitate could be detected in these crystals, by X-ray diffraction or transmission electron microscopy. The strength parameter plotted in Fig. 1 is the inverse of the length of the slip bands spreading from a microhardness indentation made with a 50-gm. load. Figure 2 shows how etching the crystal in hot nitric acid reveals the slip bands. This parameter was found to correlate much better than the microhardness with the flow stress in bending. Thus, a quenched crystal containing 1.35 cation % Fe had a flow stress in bending 2.3 times that of the original crystal. The corresponding increase in the inverse slip-band length was by a factor of 2.4, while the microhardness increase was barely detectable. The increase in flow stress is not due to impurity-pinning of the dislocations already present, since fresh dislocations were introduced through surface damage before bending. The strengthening of the quenched crystals can be attributed to the presence of ferric rather than ferrous iron. This was discovered by heating a crystal in an atmosphere of low oxygen pressure, which converted the iron to the ferrous state and removed the strengthening.

The strength of a quenched alloy crystal can be increased by aging in air. Figure 3 shows how the inverse slip-band length changed when two halves of the same crystal were aged at 800° and 900° C, respectively. A finely dispersed precipitate can be de-

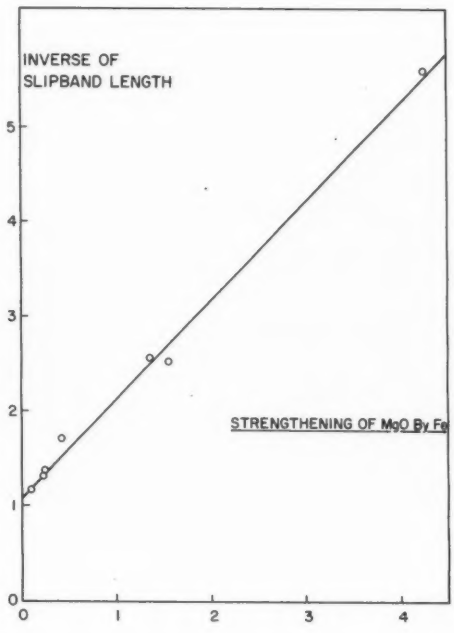
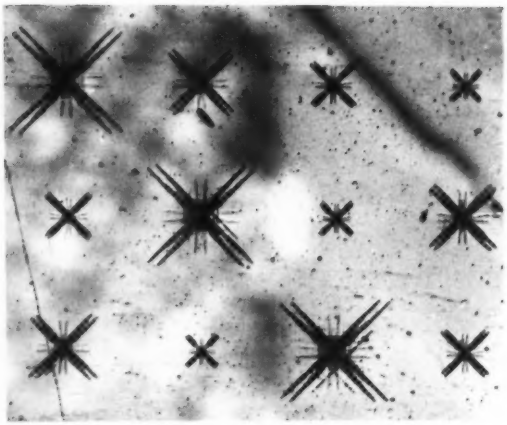


FIG. 1 Ionic Concentration Fe%.



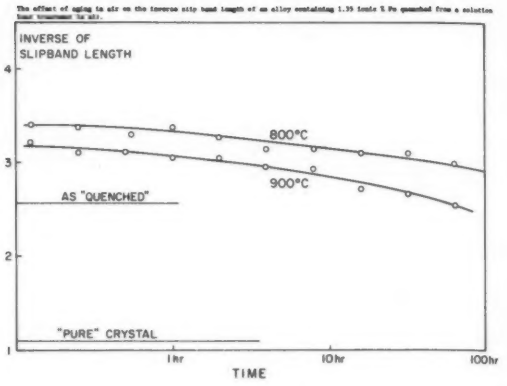
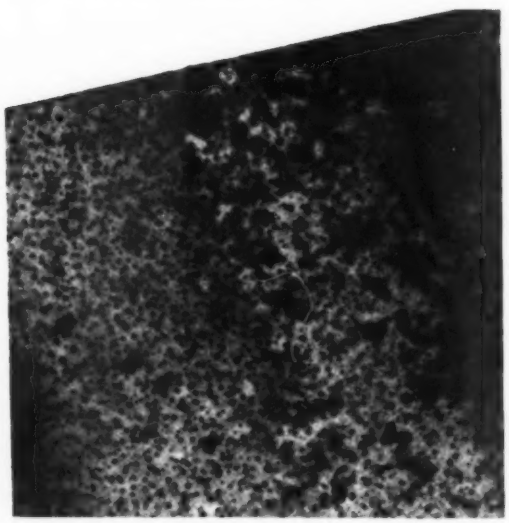


FIG. 2 Microhardness indents of various loads on the surface of an MgO crystal after etching to reveal slip bands. The longer slip bands lie in (110) directions.

FIG. 3 The effect of aging in air on the inverse slip band length of an alloy containing 1.35 ionic % Fe quenched from a solution heat treatment in air.

tected during the early stages of aging. Figure 4 is a transmission electron micrograph which shows that the precipitate is oriented within the MgO matrix. Each precipitate particle is believed to be an octahedron, the faces of the octahedron being (111) planes. Continued aging coarsens the precipitate without changing its shape or orientation. After aging for 15 minutes at 800° C, the flow stress in bending of a crystal which contained 1.35% Fe/Fe + Mg was 2.9 times that of the unalloyed crystal; but the crystal fractured at a much smaller strain than would have an unalloyed crystal.



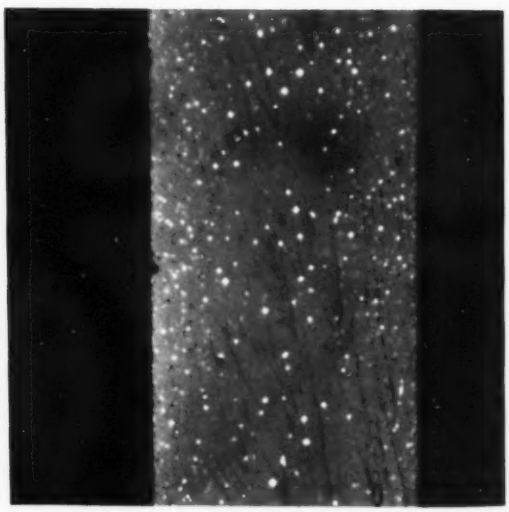


FIG. 4 Magnesioferrite precipitate in an alloy containing 4.25 ionic % Fe after aging for 20 minutes at 900° C. A similar structure was observed in a 1.35% Fe alloy aged for 1 hour at 900° C.

FIG. 5 Cross section of an alloy crystal containing 1.35 ionic % Fe aged in air for 16 hours at 900° C after solution heat treatment in 60% Co, 40% Co_2.

The precipitate hinders plastic flow but does not appear to significantly hinder the catastrophic propagation of a crack. Consideration of the structure of the precipitate makes this result understandable. According to the evidence of X-ray and electron diffraction, the precipitate is magnesioferrite, an inverse spinel. This is the stable second phase in the system in air. The oxygen ion sublattice of this structure is virtually identical with that of MgO, so that a continuous sublattice of oxygen ions runs throughout precipitate and matrix. It is reasonable to suppose that a crack propagating in the matrix would not experience much difficulty in continuing its path through the precipitate. A matrix dislocation has a Burgers vector which is only half the lattice translation vector of the precipitate owing to the different arrangement of cations in the precipitate, so that a fault would be produced by a matrix dislocation which passed through a precipitate. The energy needed to form such faults may be one contribution to the flow stress of an aged crystal.

The precipitate in an aged crystal is uniformly dispersed only when the alloy initially contains mainly Fe^{3+} in solution. When an alloy containing mainly Fe^{3+} is aged in air, an inhomogeneous microstructure is obtained, as shown in Fig. 5. The Fe^{2+} must be oxidized to Fe^{3+} before it can be precipitated as magnesioferrite. In the center of the crystal, away from the oxygen supply, the rate of nucleation of precipitates is kept small, and the few nuclei which do form grow into large particles. A finely dispersed precipitate is never obtained, and the strengthening that is observed when crystals containing Fe^{3+} in supersaturated solution are aged cannot be achieved under these conditions. ★

USE OF METEOROIDS TO MEASURE WIND VELOCITIES

CHARLES K. WILKE, Aerospace Instrumentation Laboratory, AFCRL

A radar system for the accurate and timely measurement of upper-atmosphere wind velocities is being developed for AFCRL by the Smithsonian Astrophysical Observatory. The system technique is one in which the ionized trails of meteors are used as natural tracers for measuring wind velocities. If the technique is successfully demonstrated, an operational system may be constructed in the Cape Kennedy area.

Wind velocities from the ground out to about 100 km are essential parameters in computing missile and satellite launch trajectories. The precision with which a missile reaches its target, or a satellite is placed in its programmed orbit, depends in part on our knowledge of wind velocities at all altitudes. The system developed for AFCRL will measure winds in the 80-to-96-km region.

An eight-station network to evaluate the use of meteoroid trails as wind-velocity tracers is now being built near Havana, Illinois. It is scheduled to be on the air by the end of this year. One of the stations is a transmit/receive station; the other seven stations are receiving stations only. The most distant station in the network is 50 km from the transmitter. The transmitter uses a double trough transmit/receive antenna, and operates at 40.92 Mcps with two-megawatt peak power. The receiving stations use yagi antennas.

The high transmitter power and system geometry will provide about 4000 echoes from meteoroids an hour. The network will monitor meteor entries within a volume of space measuring about 50 by 30 km horizontally, and 16 km (80-to-96-km altitude) vertically. The typical meteoroid entering this space has a diameter of 0.3 cm and a velocity of 72 km a second.

As meteor particles pass through the atmosphere, ionized trails are left in their paths. At altitudes between 80 and 96 km, the meteor trails are sufficiently dense to be detected by conventional radar techniques. Although the meteoroid is unaffected by the ambient wind, the ionized path is amenable

to wind transport. This, then, gives a basis for using Doppler techniques to measure wind velocities.

But to locate the meteor trail accurately in space, a more elaborate system is required. In the scheme under consideration, it is necessary to obtain information on the velocity and trajectory of the meteor. To obtain this information, more than two receiving sites must detect reflections from a particular meteor trail. Each receiving site monitors a small segment of a particular trail--namely, that segment that is perpendicular to a line drawn from the center of the receiver.

The time difference at which the echoes from these small segments are received, coupled with the known geometry of the sites and the echo information, provides the basis for calculating the trajectory and velocity of the trail--and thus the spatial location of each echo source.

The aggregate of the information obtained during a period of time enables computation of the three components of wind velocity at various altitudes within the sampled volume--that is, the computation of an accurate wind profile. A program for an IBM 7090 computer will be prepared for data reduction and profile plotting. The system also provides basic data on meteors in general--their trajectory, rate, velocity, deceleration and electron distribution.

The Havana, Illinois network is one of two radar systems concerned with the use of ionized meteor trails as tracers for measuring wind velocity. The other system, operated by the Meteorology Laboratory and located at AFCRL in Bedford, Mass., is being used to obtain winds and densities from 80 to 105 km. This single-station transportable set is currently limited to 30-kilowatt peak power by the FCC and operates on either 36.8 or 73.6 Mcps.

The primary objective of the transportable set is to obtain information at a number of different locations for studies of the general circulation and for developing techniques for predicting wind and density profiles which are needed for vehicles re-entering the earth's atmosphere from the moon or beyond. ★

Peruvian Rocket Launch Site Planned

JAMES F. MURPHY
Office of Deputy for Logistics, AFCRL

The Air Force Cambridge Research Laboratories plan to set up a temporary rocket-launch site at Ancon, Peru, at the magnetic equator. A five-man evaluation team left AFCRL on 21 September 1964 for Peru to investigate the proposed location. AFCRL is working with the Peruvian military establishment in setting up the new site. If the site is selected, it will become operational in the late summer or fall of 1965 and will be operated with the help of the Peruvian military establishment.

The angular distribution and flux of electrons trapped in the earth's radiation belts at the magnetic equator are of great interest to the environmental scientist. From the launch site, AFCRL scientists will be able to obtain a complete vertical profile of electron densities not only in the radiation belts, but in the earth's ionosphere as well.

AFCRL is interested in diurnal, seasonal, and solar-induced variations in electron densities in the region of the equator. The Peruvian launch site will permit scientists for the first time to obtain a complete vertical profile of electron distributions over the magnetic equator. ★

scientific note

Scientific Note: A Nike Apache vehicle was successfully launched from the Eglin (Florida) Gulf Test Range on 17 October 1964. The objective was to perform controlled chemical-release experiments in the ionosphere to determine winds and temperatures and to provide flight evaluations of a prototype release system. The effects of these chemical releases were observed by optical ground measuring equipment.

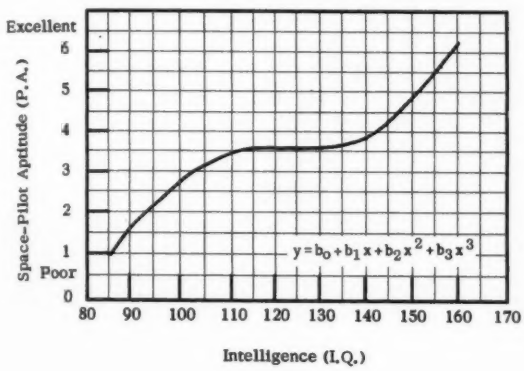
(Upper Atmosphere Physics and Aerospace Instrumentation Laboratories, AFCRL)

The Problem of PREDICTING SPACE-PILOT APTITUDE From Intelligence

ALFRED CRANCER, JR.
Directorate of Mathematical Sciences, AFOSR

The usefulness of the statistical theory developed by Paul G. Hoel under an AFOSR research grant (1) can be demonstrated by an example. Consider the problem of predicting space-pilot aptitude from intelligence. Let P.A. (Pilot Aptitude) represent space-pilot aptitude and I.Q. (Intelligence Quotient) represent intelligence. The graphical representation of the regression of space-pilot aptitude on intelligence might appear as follows:

Relationship of Space-Pilot Aptitude and Intelligence



Suppose that Air Force officers are available for testing who have I.Q.'s in the range of 100 to 140, and that budget and time considerations allow for the testing of not more than 52 subjects. In addition, let us suppose that we are especially interested in the P.A. score for an I.Q. of 160 when the P.A.'s associated with the I.Q. levels have a common standard deviation of 1.

The problem to solve is one of selecting I.Q. levels and the proportion of subjects to test at each I.Q. level which will minimize the variance of the predicted value of P.A. on the regression curve at an I.Q. of 160.

A commonly used procedure would be to select 4 I.Q. levels (because we are dealing with a 3rd-degree polynomial) equally spaced from 100 to 140, and to select an equal number of subjects at each level as follows:

I.Q.	Number of Subjects
100	13
113	13
127	13
140	13
	52

The variance of the predicted value of P.A. for an I.Q. of 160 based on the above spacing and weighing of I.Q. levels is about 20.

A significantly smaller variance of the predicted value of P.A. may be obtained by applying the surprisingly simple formulas for optimum spacing and weighing developed by Hoel. The optimum spacing and weighing of I.Q. levels for this problem would be as follows:

I.Q.	Number of Subjects
100	5
110	12
130	20
140	15
	52

The associated variance of the predicted value of P.A. for an I.Q. of 160 using optimal weighing and spacing is 13. Thus, the commonly used procedure yields a variance that is over 50 per cent greater than that of the optimum procedure.

In summary, the theory developed by Paul G. Hoel under an AFOSR research grant is of immediate use in problems involving polynomial regression. The results developed in this paper will also generate further research in determining optimal weighing and spacing solutions for other types of regression functions. ★

(1) Hoel, P. G. and A. Levine, Optimal Spacing and Weighing in Polynomial Prediction.

Some In-House Research

Photo 1

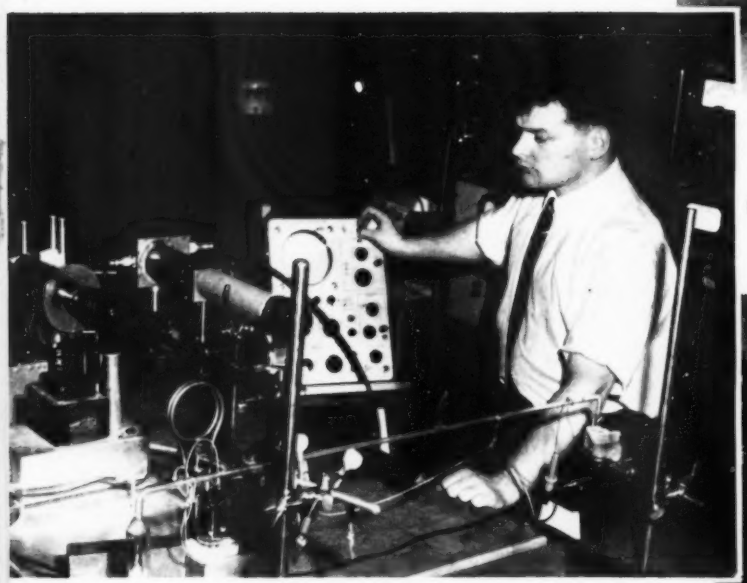


Photo 2

Photo 3

Photo 1 *Mr. Otto Walchner of the Hypersonic Research Laboratory, ARL, studying Schlieren photographs in his investigation of aerodynamic stability problems.*

Photo 2 *Dr. Alan Garscadden from Belfast (Queens University), now a member of Plasma Physics Research Laboratory, ARL, working on wave propagation in a mercury plasma and on the investigation of radio-frequency probes.*

Photo 3 *Dr. Frank Chan of the Chemistry Research Laboratory, ARL, using a G.E. GRD-5 X-ray machine for crystal analysis by the fluorescent method.*

Efforts at ARL

Photo 4

Photo 5

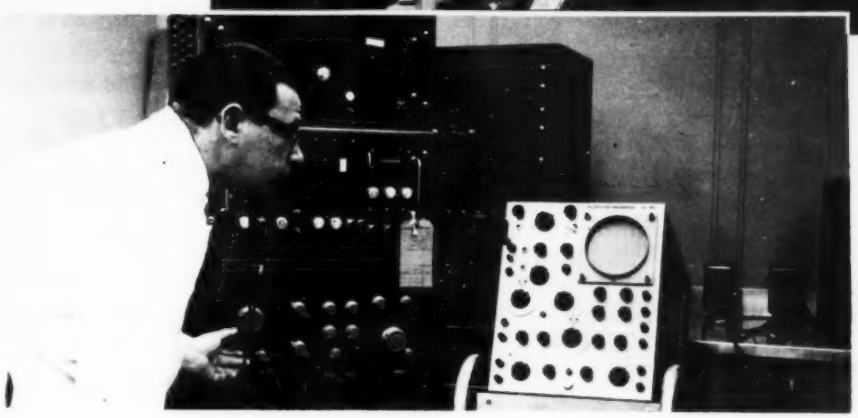


Photo 6

Photo 4 *Mr. Henry Fettis (seated) and Mr. James C. Caslin of the Applied Mathematics Research Laboratory, ARL, at IBM 1620 computer.*

Photo 5 *Dr. Dietrich W. J. Langer of the Solid State Physics Research Laboratory, ARL, studying effects of extremely high pressure on the optical and electrical properties of semiconductor materials.*

Photo 6 *Changes in dielectric properties of Al_2O_3 are being measured on apparatus designed by Dr. Norman Tallan of the Metallurgy and Ceramics Research Laboratory, ARL.*

Atmospheric Limitations On Laser Propagation

METEOROLOGY LABORATORY, AFCRL

Coherent laser communication and detection systems will probably be feasible only in outer space. Put in another way, we cannot expect to modulate a laser signal as we would modulate a radio signal in a laser communication or detection system designed to operate within the earth's atmosphere. The reason for this is that the normal atmospheric turbulences impress an undesirable modulation on the transmitted beam which garbles intelligence.

These conclusions were reached by Bernard A. Silverman of AFCRL following a detailed study of the effects of the atmosphere on laser propagation. In this study, attenuating and disturbing atmospheric influences became strongly apparent. These influences were molecular absorption, Rayleigh and aerosol scattering, attenuation by clouds, diffraction-limited range attenuation, and atmospheric turbulence. The last of these, atmospheric turbulence, created a special set of difficulties and posed the greatest obstacle to laser communications.

Lasers operate in a wave-length region where absorption by atmospheric gases is considerable. Water vapor, carbon dioxide, and molecular oxygen are the principal attenuating constituents. Nevertheless, because absorption is highly wave-length dependent, there are "windows" where absorption is small or nonexistent. An examination of 76 different laser systems over a range of wave lengths from 6129.5 to 203,215 Angstroms shows that 24 have little or no atmospheric absorption, 17 are almost totally absorbed, and 35 fall near enough to absorption lines to make their use questionable.

Molecular absorption is only one of several factors embodied in a fundamental equation of transmission losses for laser propagation in the atmosphere developed by Silverman. This equation describes the relationships between the several atmospheric effects and such system parameters as power transmitted, areas of transmitting and receiving antennas, wave length and distance.

Using this equation, Silverman has computed the attenuation of a laser beam on an atmospheric model representative of average conditions. Atmospheric conditions, of course, vary greatly with location. We would naturally expect greater attenuation over a smog-polluted city than in mountainous regions.

Absorption and scattering are well known and can be estimated with reasonable precision in designing a laser-communication system. Far more serious is atmospheric turbulence. Astronomers classify such turbulence under the general category of "seeing." Three turbulence effects are involved. One is scintillation (twinkling) or changes in intensity in a random fashion; scintillation is highly correlated with winds in the troposphere. Another is dancing, or the motion of the beam over several seconds of arc in a random manner about a mean position. The last is changes in shape, in which the light reaching the receiver seems to change its shape like an amoeba. Both this effect and dancing result from atmospheric influences near the ground.

Turbulence is associated with all types of atmospheric motions--acoustic disturbances, thermal inhomogeneities, convection streams and so on. A series of experiments were conducted in which laser transmissions were made over a quiet atmospheric path. A variety of controlled disturbances introduced along the path indicated that slight thermal disturbances create considerable degradation in beam coherence, whereas air turbulence by itself has little effect.

Since "seeing" disturbances are introduced mainly within about 300 feet of the earth's surface, the best way to minimize them is to install the laser terminal in a tower, on a mountain top or in a tall building. The tower, mountain or building may itself in-

troduce turbulence; but the distance that the beam must pass through thermally turbulent air is very short. Inversion layers constitute another thermally turbulent region. If the terminal can be located above common inversion levels, this will also help.

In this study, Silverman examines four modes of laser-communication operations: space to space, earth to earth, space to earth, and earth to space. Only in a space-to-space link does coherent laser communication appear to be generally feasible. The other three modes must necessarily involve incoherent detection of the signal.

While incoherent detection of the entire signal is a problem in all modes of operation, by far the most difficult mode of operation is from the earth through the atmosphere to a space station. The difficulty arises from the consequences of beam scanning caused by thermals near the transmitting laser. The receiving telescope aperture at the space station cannot be made large enough to receive the randomly scanning beam. This difficulty can be overcome by making the transmitting telescope very large and of astronomical quality; but this is very costly.

The Silverman study has implications not only for laser-communication systems, but also for laser weaponry and laser radar. This study is one of the first ones in which the problem of atmospheric limitations to laser propagation is being realistically confronted. ★

NEW Speech-Synthesis TECHNIQUE

DATA SCIENCES LABORATORY, AFCRL

Of the many elements making up a digital speech-compression system, one of the most critical is the speech synthesizer--for obvious reasons. It is this element that generates the appropriate wave forms used to recreate the original speech signal. Ideally, it will produce a wave form resulting in an intelligible and natural voice signal, preserving the original inflection and permitting easy speaker recognition. It would not have the flat, mechanical sound that is often characteristic of processed speech.

Because of the importance of speech synthesizers, much of the research in speech compression (research concerned with reducing the amount of band width needed to transmit a speech signal) has been devoted to the special problem of speech-synthesizer design. Such research at AFCRL has led to a new technique for speech synthesis.

The new technique was conceived by C. P. Smith of AFCRL. The synthesizer offers significant advantages in size, weight and cost in addition to fundamental improvements in intelligibility and quality. Speech synthesizers, in general, are a part of vocoder systems. The vocoder receives, as an input, digital information which describes the characteristics of the original speech signal. When operated with conventional synthesizers, the vocoder generates wave forms that are passed through channel filters at discrete frequency ranges. Conventional synthesizers use the output from the channel filters for their operation.

In the technique developed by Smith, which is based on analog simulation, simple multivibrators and control circuits replace the channel filters. These multivibrators produce the pitch-synchronous wave forms that are a close approximation to the wave forms generated in human speech. An experimental model has been constructed under contract. It has already demonstrated its ability to produce high-quality, highly intelligible speech. The synthesizer has been called a "Vocal Response Synthesizer" because it synthesizes the response wave forms of the vocal resonances. It is especially suited for microminiaturization of a vocoder because of the circuit simplification and the elimination of inductors.

Speech-compression research, of which the synthesizer is a part, is of interest to the Air Force for several reasons. First, for a given amount of band width, more communication channels become available. Second, for a given amount of power, a narrow-band signal can be transmitted a greater distance than a signal carried over a broader spread of frequencies. Last, digital processed speech readily lends itself to encoding. ★

Six AFCRL scientists recently returned from Sweden after concluding the second in a series of rocket flights to collect noctilucent cloud particles. The rocket-borne experiments, carried out jointly by AFCRL, the Swedish Space Committee and NASA, were conducted at the Swedish Kronogard Range. In the above photograph, taken on the Kronogard Range in Sweden, AFCRL scientists prepare for a rocket flight to collect noctilucent cloud particles. Shown with one of the nose cones in front of the "clean room" are two of the AFCRL scientists and three AFCRL contractor personnel. Standing (left to right) are Dr. Robert Soberman, in charge of the AFCRL group; Richard Morin, Wentworth Institute; Stanley Chrest, AFCRL; and Robert Sarkisian, Dudley Observatory. Kneeling is Warren Harding of Northeastern University.

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